Meter-Scale Single-Wall Carbon Nanotube Films for the Use in Flexible and Transparent Integrated Circuits

Dong-Ming Sun, Bing-Wei Wang, Chang Liu, Hui-Ming Cheng
Shenyang National Laboratory for Materials Science, Institute of Metal Research, Chinese Academy of Sciences, 72 Wenhua Road, Shenyang, 110016, P. R. China
School of Material Science and Engineering, University of Science and Technology of China, 96 Jinzhai Road, Hefei, 230026, P. R. China
dmsun@imr.ac.cn

1. Introduction

Thin films composed of single-wall carbon nanotubes (SWCNTs) have been demonstrated as transparent conductive film electrodes or semiconducting active channels in various flexible and transparent electronics.[1,2] However, two major obstacles remain for the research and development of macro-electronics based on SWCNT thin films. First, the size of fabricated SWCNT films is usually limited to the square centimeter scale, and the batch processing used is not scalable. SWCNT films, either deposited by a gas/liquid vacuum filtration or synthesized by chemical vapor deposition (CVD), are usually smaller than, or close to, the size of membrane filters and/or growth substrates. Second, the optoelectrical performance of SWCNT films remains unsatisfactory due to the introduction of impurities and structural defects during the solution processes of film fabrication, such as dispersion, purification and separation. In this study, we propose a continuous synthesis, deposition and transfer technique for the fabrication of high-quality SWCNT thin films of meter-scale dimension with excellent optoelectrical performance.

2. Results

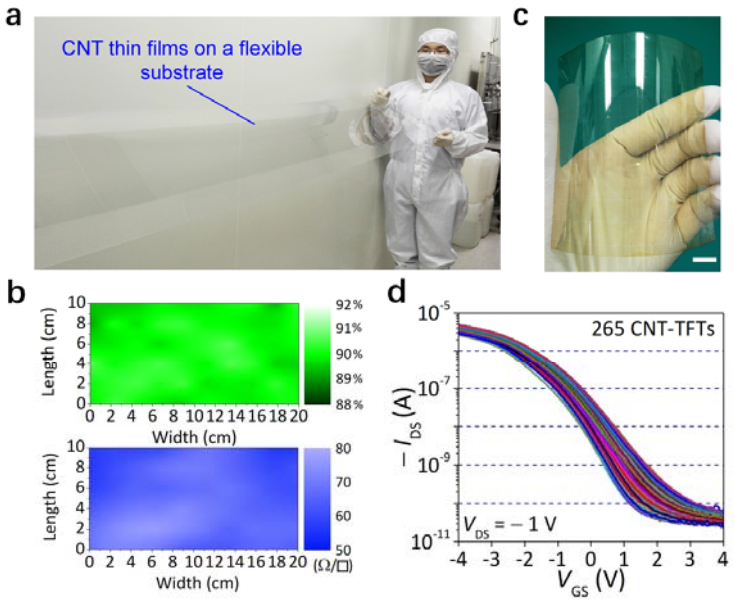

Fig. 1. (a) A SWCNT thin film transferred on a flexible PET substrate with a length of more than 2 m. (b) Transmittance (upper) and sheet resistance (lower) mapping,of the as-prepared SWCNT thin films. (c) Photograph of all-CNT TFT device fabricated on a flexible PEN substrate with a size of 100 × 100 mm^2 (scale bar, 10 mm). (d) Transfer ($I_{DS} - V_{GS}$) characteristics of 265 TFTs at $V_{DS} = -1$ V.

The SWCNTs are continuously synthesized by a floating catalyst chemical vapor deposition (CVD) technique. The maximum width of the SWCNT thin films obtained is 0.5 m, and can be adjusted by selecting different filtration windows of various dimensions. The length of the film is unlimited, because the as-deposited film is transferred onto a flexible polyethylene terephthalate (PET) substrate with the aid of a roll-to-roll transfer system, and the filter can be repeatedly used for CNT film collection. The meter-scale SWCNT film deposited on the membrane filter can be easily transferred onto a target substrate, thus allowing us to construct large-area all-CNT devices. The good reproducibility and uniformity of the fabricated all-CNT TFTs allow us to construct logic ICs. A 101-stage ring oscillator with an output buffer, where 204 all-CNT TFTs were integrated on a PEN substrate spontaneously begins oscillating at a V_{DD} of −3 V. The successful operation of the ring oscillator indicates excellent uniformity of the SWCNT thin films and the all-CNT TFTs.

3. Acknowledgement

The authors sincerely thank Prof. Esko I. Kauppinen, Mr. S. Jiang, Dr. S. Qiu, Prof. Q. Li for their constructive advices.

4. References

[1] Y. Chen, Y. Sun, Q. Zhu, B. Wang, X. Yan, S. Qiu, Q. Li, P. Hou, C. Liu, D. Sun and H. Cheng, Advanced Science, 1700965 (2018).
[2] L. Zhang, D. Sun, P. Hou, C. Liu, T. Liu, J. Wen, N. Tang, J. Luan, C. Shi, J. Li, H. Cong and H. Cheng, Advanced Materials, **29**, 1652719 (2017).
[3] X. Li, Z. Fan, P. Liu, M. Chen, X. Liu, C. Jia, D. Sun, X. Jiang, Z. Han, V. Bouchiat, J. Guo, J. Chen, Z. Zhang, Nature Communications, **8**, 970 (2017).